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O B S E R V A T I O N S
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E F F E C T S O F B L E E D I N G.

By J O H N H U N T,
A M E M B E R O F T H E C O R P O R A T I O N O F S U R G E O N S.

L O N D O N:

P R I N T E D F O R J. J O H N S O N, N O. 7 2, S T. P A U L ' S C H U R C H -
Y A R D; A N D C. E L L I O T, E D I N B U R G H.

M D C C L X X V I I.

[P R I C E T W O S H I L L I N G S.]

OF THE

CIRCUIT

OF THE

STATE OF

NEW YORK

IN SENATE

AND

ASSEMBLY

1880

P R E F A C E.

MOST Readers will allow, that Anatomy and Physiology may justly be considered as the true basis of Medical Knowledge; and perhaps no part of them is more intimately connected with the practice of Physic, than that which is the subject of the following pages. I hope therefore that the importance of the object of these enquiries will in some degree justify their publication, and that the number of books that have been already written nearly on the same subject will not be considered

as a sufficient objection to any further enquiry, so long as the present theory of the action of the arteries remains in a state of such uncertainty and imperfection.

THE following arguments would perhaps have met with more general approbation, if I had endeavoured to support the different opinions that I have advanced by what are commonly called matters of fact, such as were either deduced from experiments, or collected from cases where one certain method of treatment has appeared more efficacious than another. With respect to experiments, I think they are sufficiently numerous already, and that more have been made than well explained. But if the authority of experiments is thought necessary, those that have been made with the greatest accuracy, and faithfully recorded by Haller, Dr. Hales, and a few others, are sufficient to prove to a demonstration every one of the following observations; and as for a history of successful

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or unsuccessful cases, I must agree with Mr. Pott *, that they cannot be much depended on : but as the following arguments are more particularly addressed to the Faculty, and not calculated for the general class of Readers, every one that is so inclined may try their validity by his own practical observations. However, it will be necessary to consider, that though by one certain method of treatment the patient received evident relief, and even recovered from his disease, this is no positive proof that if some other method had been used, and that omitted, that the treatment would not have been

* Mr. Pott (in the Preface to his Observations on Wounds on the Head) says, "I could produce many histories to confirm my assertions, if I thought that they would add to their use or force, but have suppressed them, because they do not appear to me likely to do either ; as the reader must still depend upon my veracity, as much in one instance as in the other: the man who is capable of asserting what he knows to be false, must have a very defective imagination not to be able to form cases in its support."

been more efficacious. For instance, suppose in case of apoplexy, a pound of blood was taken from the temporal artery, and the patient recovers, it will be impossible to determine that this method was preferable to every other, or even that if the patient had been bled in the arm, the advantage would not have been more considerable, and the recovery more complete; or suppose in a similar instance, the temporal artery was opened, and the patient died, we cannot from the want of success determine what might have been the consequence, if a vein had been opened instead of an artery.—So that it is not possible that the advocates for the different opinions should ever with any degree of certainty decide the point in question from † the evidence of a few cases; for though facts are generally considered as incontestible arguments, at the same time it will be necessary to remember, that by a mis-application

† Sharp's Critical Enquiry, p. 255.

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application of facts, it is very possible to give the appearance of plausibility to the most palpable absurdities; and an improper choice of facts will be productive of as great uncertainty. The facts themselves should first be well considered, and every compound fact should be critically analyzed, before it is admitted as the foundation of any theoretical argument.—The simple operations of the animal œconomy are the only facts that can be depended upon in this instance; and even these simple facts will prove of little service without a rational theory to connect them. Facts without doubt are the foundation of theory, but it is theory which teaches how to connect simple facts in the proper order in which they naturally succeed each other; it is theory which teaches how to trace evident facts to their remote, if not to their first causes—and also how to distinguish causes from effects, and effects from causes:—The object of theory is therefore the acquiring a clear, distinct, and accurate

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rate knowledge of the first principles and laws of nature; and thus without theory, the accumulation of facts must undoubtedly prove an unintelligible chaos. At the same time it will be necessary to observe, that that theory which is the production of a fertile imagination, and only founded on book-knowledge, without a proper foundation of well known facts, when formed with a certain degree of plausibility, must undoubtedly prove, before all others, the greatest impediment to every species of philosophical investigation.

THE method that I have pursued in the following pages appeared to me best adapted to my present purpose, and the limits of the subject have been determined by the nature of the objects of enquiry. I have studiously endeavoured to copy Nature, without being influenced by the opinions of others; and if the matter is thought worthy the attention of the Reader, I hope the manner,

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ner, if intelligible, will be excused with all the imperfections: for though purity of language and elegance of style are ornaments that should never be neglected, they do not appear so absolutely necessary on this occasion, as it is not the construction of words and sentences that is the object of these enquiries, but the anatomy of the arterial system, and those laws of the animal œconomy, which regulate and influence the motion of the blood.

T R A C T

now it is possible, will be excited with all
the impetuosity: for it is the nature of man
to be easily moved by the ornaments
and the force of the passions, and the
appeal to the passions is the most
powerful, as it is not the reason of words
and knowledge that is the object of the
passions, but the nature of the
passions, and those laws of the passions
which are the objects of the passions
and the passions are the objects of the passions.

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OBSERVATIONS
ON THE
CIRCULATION OF THE BLOOD, &c.

SECTION I.

Of the present State of this Part of Physiology.

THE course of the blood through the heart and lungs, and through the arterial and venal systems, was first demonstrated by the great HARVEY ; but the different animal functions that promote the circulation of the blood, have been explained by slow degrees. The principles on which the systole and diastole of the heart depend, was a subject that engaged the attention of the first physiologists, but was

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little

little understood, until Haller published his Experiments on Irritability, which were afterwards farther illustrated by Whytt's Essays on the Vital and other involuntary Motions of Animals; and even at the present period, as our knowledge of the construction, powers and properties of various parts of the animal body, remains very imperfect; so in particular, the action of the arteries and the motion of the blood through their cavities, have never yet been perfectly explained, or generally understood.

IN the following disquisitions on this subject, I shall carefully avoid the admission of such doubtful experiments as may give various appearances for want of sufficient accuracy in the operation, or may at least admit of different conclusions; and shall only attend to a few evident facts, that are well known to every anatomist, and may be repeatedly observed without the least hazard of want of uniformity in the most important circumstances: by which means many difficulties will be avoided, which, in similar instances, instead of explaining the principles

ciples of nature, have proved the foundation of innumerable errors; and the subject that was intended to have been thereby illustrated, has been left in greater obscurity. Equal difficulties would undoubtedly attend every attempt to explain that property of the arteries which is the cause of their muscular action, by the most accurate repetition of such experiments that have been made on living, or more strictly speaking, on dying animals, on the subject of irritability, and for this evident reason; because, in all enquiries into the laws of the animal œconomy, it is necessary that the several parts should be in a perfect † state, and actuated by the powers of nature only, which is not consistent with the nature of those experiments that have been used to determine the existence and degree of irritability or sensibility of different parts; and for want of attention to this particular, every experiment will be attended with ambiguity, and the most refined and plausible arguments will prove exceptionable, and subject to the following objections.

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† Whytt on Sensibility, p. 261.

THE pain that the animal would suffer by the dissection to expose an artery, might considerably diminish, or totally destroy, the natural irritability of the part; or the division of the vessel might do so much injury to the muscular coat, that the power of action might be destroyed, and the vessel not contract, though it was effectually irritated; or cutting the vessel to get at the internal surface, might prove a stronger stimulus than what would be afterwards applied; and as it would be difficult to evacuate all the blood, which is the proper stimulus provided by nature, and impossible to prevent the admission and contact of the air, which might prove a stimulus; consequently the vessel could not be observed but in a state of irritation.

BUT when our enquiries are directed to subjects of much less difficult investigation, we are frequently deceived by attending to the delusive appearances of anatomical experiments; if we do not at the same time attentively consider the true principles upon which these appearances depend. For instance, the appearances that take place when the carotid arteries are divided,
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are so very different to what is observable when a small artery is divided, or when one of these vessels is only slightly wounded, that this single circumstance has given rise to an hypothesis §, which, contrary to the general opinion, supposes that there is neither systole or diastole in the arteries, and that the blood moves through their cavities with a regular and unremitting velocity. But the natural course of the circulation is so changed when the carotid arteries are divided, that this experiment cannot possibly lead to any such conclusion, but, on the contrary, this furnishes us with an instance that evidently proves the effects of diminished resistance in any part of the arterial system. That I might be perfectly satisfied of the certainty of the fact, I repeated the experiment, and found that when the carotid arteries of a sheep were suddenly divided, the blood was discharged from their cavities with a continued stream, and with uniform velocity, and that there was not the least motion to be perceived in the divided vessels, until the greatest part of the blood was evacuated. What at first

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view

§ Dr. Kirkland's Medical Surgery, Vol. I. p. 307.

view appears most singular in this experiment is, that though the blood is propelled from the heart at intervals, the discharge from the carotid arteries should be constant and regular—and it is also necessary to observe, that the quantity of blood that is discharged in a given time far exceeds the quantity that passes the heart; for if the dimensions of the left ventricle of the heart, and the number of pulsations be nearly ascertained, the quantity of blood that enters the aorta from the heart in the same time, may be estimated with sufficient accuracy by a mental calculation, to give the most evident proof of the truth of this assertion; consequently the blood must come some other way, to pass through the divided vessels. And as the semilunar valves placed at the origin of the aorta are the only valves in the whole arterial system, there is no impediment to prevent the return of the blood from the extreme ramifications of the arteries, towards the divided carotids, where all resistance is destroyed; and thus the blood being pressed by the natural contraction of the arteries, and by the convulsive action of the circumjacent muscles, will return from all the extreme

trême parts of the arteries, and the whole contents of the arteries returning at the same time by the aorta descendens and the two subclavians, together with what comes through the aorta ascendens from the heart, will occasion a supply in the curvature of the aorta, that will exceed the discharge at the divided carotids; consequently the superior part of the aorta will be distended by the pressure of the accumulated blood*; and the re-action continuing the same without intermission, will force the blood through the carotid arteries with a regular and uniform velocity. But it is impossible that this effect should be produced by the power of the heart alone: if it was not for these co-operating powers, that continue to act during the diastole of the ventricle. For the distance from the left ventricle of the heart, through the cur-

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vature

* Haller's Dissertation on the Motion of the Blood, p. 102. When either the heart or the aorta is cut off, generally the blood of the mesenteric arteries moves retrograde. Ibid, p. 143. The blood of an animal whose heart is destroyed, doth not move only from great vessels to small ones, but it more frequently moves from the small branches to the great ones. See also p. 139.

varure of the aorta to the open orifices of the divided carotid arteries is so short, and as the blood will meet with no resistance† when the continuity of these vessels is destroyed, these vessels would be very little distended, and the blood would be discharged at intervals, corresponding to the motions of the heart, which is evidently proved by what takes place before the conclusion of this experiment; for as the whole arterial system is perfectly evacuated some little time before the death of the animal, and as the heart still continues to transmit the blood from the cava to the aorta, the blood is then discharged from the divided carotids at intervals, corresponding to the systole of the left ventricle; and the veins at that time being also nearly evacuated, the quantity of blood that supplies the heart will be diminished at every pulsation, and consequently the action of the heart, and the quantity of blood discharged by the carotids at each impulse, will gradually diminish, until the animal expires. From this and similar instances, it is reasonable to conclude, that the operations of nature,

† Critical Review, April 1783, p. 256.

nature, in the most simple and perfect state, will prove the safest guide to truth; and those parts are most proper for observation that are evident to the senses, without the assistance of optical instruments: for if the laws of the animal œconomy cannot be investigated by attending to the operations of those parts that are evident to the sight, and are capable of being examined by the fingers and dissection, it is not probable that the result of our enquiries will prove more successful when we attempt to investigate those parts that are in themselves too minute to be seen without the assistance of the microscope, and but imperfectly with it. In my opinion, the microscope has never much enlightened this subject; but on the contrary, it has given some authors a fine opportunity of describing whatever their imaginations painted, and what no eyes but their own have ever since been able to discover: for instance, the refined and speculative theories on the doctrine of blood globules are not demonstrable at the present day; and we have every reason to believe, that, even with the same instruments, it would be impossible to repeat the same experiments with the boasted success.—

Dr.

Dr. Whytt || has attempted to demonstrate with mathematical accuracy, that the powers of the microscope are not sufficient to shew the motion of the small capillary arteries, where the blood is supposed to pass by single globules; and it appears very doubtful whether either Lewenhoeck or Hewson ever saw any such thing as a blood globule, if in reality there is any such existence in nature. Then as it is most probable that the minutiae of anatomy (which is at present very imperfectly known) will be best discovered, by observing the analogy between the large parts and the small ones;—it is very singular, that so many ingenious anatomists, who have attempted to explain the nature of the circulation of the blood, should have deduced their arguments from the uncertain evidence of microscopic observation.

|| Whytt's Works, p. 236.

SECT.

S E C T. II.

Of the Use and Abuse of Mechanical Illustrations.

THE study of mechanics has, in some degree, always been united with surgery; and the desire that has universally prevailed to become the author of some improvement in this part of medical knowledge, has introduced a number of strange uncouth instruments into every department of medicine where manual assistance is required; but the unfitness of some of these instruments for their intended purposes plainly shews the great deficiency of either the mechanical or anatomical knowledge that was necessary to have formed such instruments complete and useful. Indeed the operative part of surgery is in a great measure mechanical, and to be well acquainted with the distribution of the different parts concerned in operations, may be sufficient for such purposes; but a descriptive knowledge

knowledge of anatomy is but one part necessary towards investigating the laws of the animal œconomy. I shall not take upon me to deny, but that when certain similes are well adapted, and properly introduced, they may in some degree facilitate description, and promote the attainment of physical knowledge; but they more frequently tend to lead the mind into error, than to improve our ideas.—For instance, the late Dr. Hunter was much admired for his happy similes*; but how he failed, when he compared the aneurismal eschar to the sucker of a pump, is too evident to escape observation; and some anatomists have gone much farther, and attempted to explain the circulation of the blood on the principles of hydraulic machines, and with this intention have compared the vascular system to the different parts of a fire engine (*i. e.* an engine to extinguish fire); but the inconsistency of such a representation must appear perfectly evident to every one who has the least knowledge of the anatomy of the one, and the mechanism of the other. But as such similes have been used by different authors, and not
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* Medical Observations and Inquiries, Vol. I. p. 330.

with the most strict propriety, it becomes necessary that we examine how far they may assist our inquiries, or prove disadvantageous; and as the diastole of the arteries is chiefly mechanical, we shall find that on such principles only (as the arteries are capable of distention and contraction) it is impossible they should remain without motion. Dr. Mihles, in his translation of Haller's *Outlines of Physiology*, has added an illustration of this kind, that has attracted the attention of some anatomists †, and they have quoted the observation with the original intention, without detecting the misapplication to the mechanism of the vascular system.—The first part of the observation informs us ‡, “That a very small
 “part only of the resistance of the arteries is
 “removed each time by any single contraction
 “of the heart;” but on the contrary, I think no truth can be more evident, than that the whole resistance of the arteries is overcome by every single systole of the left ventricle; for if otherwise,

† This was taught by Mr. Else, when I attended his Lectures in 1779 and 1780.

‡ Mihles's Translation of Haller's *Physiology*, Vol. I. p. 97.



otherwise, the action of the heart must necessarily be more frequent than the action of the arteries; agreeable to that well known law in mechanics, that what we gain in power, we lose in time, and *vice versa*: and as the arteries contract as much during the diastole as they were dilated by the preceding systole of the heart, the motion of the heart and arteries will constantly and regularly correspond to each other. But to support the argument, it is then observed, "That as the semilunar valves at the origin of the aorta will admit of various apertures, the heart acts upon that hydraulic principle, whereby any force, ever so weak, by urging a fluid through an aperture proportionably small, shall overcome any resistance, or raise any weight ever so great." But as the semilunar valves have no power of action inherent in themselves, and as their motion is occasioned by the influx and reflux of the blood, the momentum of the blood will not be influenced by the opening of the valves, but on the contrary the opening of the valves will depend on the momentum of the blood; for the action of these valves is perfectly mechanichal, and they are pressed

pressed upon as powerfully by the blood in the artery, as by the blood in the ventricle of the heart: and though the femilunar valves will recede further from each other when the impulse of the blood is great, than when it is languid, that motion will be equal to the degree of velocity with which the blood enters the artery. But, to favour this hypothesis as much as possible, let us suppose that the opening of the valves depended on some power proper to themselves, by which the dimension of the aperture could be increased or diminished; even then the influence that this would have on the motion of the arterial blood would not assist the power of the heart, as is here supposed, but on the contrary, if a certain quantity of blood passes the femilunar valves in a given time, that is, if at each systole of the heart the contents of the left ventricle are impelled into the aorta, the smaller the aperture, the greater must be the velocity of the blood through that aperture, and consequently the resistance to the passage of the blood more considerable. But the principal tendency of this argument will perhaps be best explained, by comparing the power of the heart

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to the pressure of a column of water, or any other fluid of a given perpendicular, and a certain base; then if a second tube of equal dimensions be united to the bottom, and placed parallel to the first that contains the column of water, whose perpendicular pressure represents the power of the heart, they will appear like the form of a capital U, or an inverted syphon; and suppose that the pressure of the water in the second tube represents the resistance of the arteries, in this situation the gravity of the one will undoubtedly equipoise the gravity of the other, and this will be invariably the same, whether these tubes are united at the bottom by an aperture equal to the whole, or of only one tenth, or even any other inconsiderable proportion of the diameter of the tubes; which aperture, in this instance, represents the opening of the semilunar valves. Then the true reason why a feeble contraction of the left ventricle of the heart after fainting, &c. is capable of renewing the circulation, is, because the arteries, during the cessation of the motion of the heart, having nearly completed their vacuity, and consequently their distention being diminished, their resistance will

will be diminished in proportion, and then a less powerful impulse of the heart will be sufficient to restore the motion of the blood; and at the same time; as the irritability of the arteries will be diminished, their muscular action will not be so powerfully excited by the stimulus of the blood, and their power of re-action as much diminished as the power of the heart, and the just proportion between the power of the heart and the resistance of the arteries be equally preserved. But it is not necessary to my present purpose, that I should point out every error of this kind that might be selected from different anatomical writings. I only wish to examine some of the most exceptionable opinions, and answer their principal arguments; and the following instance seems to comprehend every particular that is necessary to be advanced on this subject: and I should think myself guilty of a great omission if I let this observation pass unnoticed, as it has been employed to support an opinion contrary to that which is delivered in the following pages; and some readers might conclude that all I have written on the action of the arteries

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would

would sink under the authority of this important argument.

IN this observation the circulation of the blood is compared to the operation of a fire engine *, *i. e.* an engine used to extinguish fire, and the hydraulic principles of the one are supposed to give a perfect representation of the other. But if we consider the mechanism of a fire engine, and the construction of the vascular system, it will not be difficult to discover the impropriety of this simile, and the bad tendency of such delusive illustrations. But before we proceed to examine the general tendency, it will be necessary to observe, that the arteries are not conical, but perfect cylinders; the necessity of which form will be shewn in the following section:

* Dr. Kirkland has asserted, that “ If the leathern
“ tube of a fire engine were made elastic, and somewhat
“ conical like the arteries, I doubt not, were its end at
“ liberty, or inclosed in a ligature, but it would undergo
“ a similar motion from the passage of the water. And
“ I am persuaded this instrument represents the manner
“ in which the blood is made to circulate through the
“ body.” Medical Surgery, Vol. I. p. 313.

section. First, to give a short description of a fire engine, that it may be sufficiently understood for the present purpose: it is composed of two forcing pumps that act alternately; a large air vessel, in which the air is condensed by the pressure of the water; a long cylindrical leathern tube, at the end of which is fixed one made of brass or copper, of a conical form, by means of which the external orifice of the tube, which is the outlet of the engine, is diminished, and the velocity of the water proportionably increased; and thus by the successive action of each embolus in the cylinders, the two cylinders alternately discharge their contents into that part of the engine that communicates with the air vessel; and as the re-action of the condensed air on the surface of the water is constantly equal to the power of the engine, the lateral pressure of the water against the sides of the leathern tube will be regularly the same, so that was the leathern tube ever so elastic, as the distending power acts without intermission, the tube will not dilate and contract, but will remain in a state of distention equal to the lateral pressure of the water. But on the contrary, when

a quantity of blood is discharged into the aorta by the contraction of the heart, the systole of the left ventricle immediately ceases, and the arteries that were distended by the ingress of the blood, have time to contract and regain their former dimensions; for the contents of the arteries are propelled with different degrees of power at different intervals, being actuated most forcibly when the arteries are most distended, and least so when they are most contracted. But here it will be necessary to observe, that the pressure of the condensed air does not add to the power of the engine, as has been supposed by some writers †; it only sustains the pressure of the water; and, whilst the engine is in motion, constantly re-acts with a power equal to its condensation. But although the operation
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† Dr. Mihles supposes, “ that to the power of the heart
“ the arteries serve as a multiplying spring, by their
“ elastic force proportionable to their distention; and
“ drive forward the blood and continuous juices in the
“ same manner as the air by its spring throws out a con-
“ tinued stream, with a celerity proportionable to its
“ compressure in the fire engine, or forcing pump.”
Translation of Haller's Physiology, Vol. I. p. 97.

of the fire engine bears very little analogy to the circulation of the blood, the operation of a single forcing pump with a long leathern tube will be found to be somewhat similar to the action of the heart and arteries, for when the capacity of the cylinder of the pump is increased by the ascent of the embolus, the water rushes in to supply the vacuum, so does the blood into the evacuated ventricle of the heart; and as the blood is forced into the aorta by the systole of the ventricle, so when the capacity of the cylinder is diminished by the descent of the embolus, the water is forced into the leathern tube, and as often as the water is forced into the leathern tube, it will be evidently dilated, and when the acting power ceases, the tube will immediately contract by its elastic power: and thus by the repeated action of the pump, the leathern tube will alternately dilate and contract in a manner somewhat similar to the diastole and systole of the arteries; and if the arteries were nothing more than elastic membranes, and perfectly void of muscular power, they would even then dilate and contract in the same manner as the leathern tube, but it is impossible that they should be perfectly free from motion, unless their resist-

ance was greater than the lateral impulse of the blood.—As for the operation of any hydraulic engine, that can only be mechanical; but the animal functions are influenced by powers that depend on very different principles: so that the most accurate description of the one will give but a very imperfect representation of the other. But if what has been said on this subject is not sufficient to convince every impartial reader of the bad tendency of this method of reasoning, let him consider how the great Boerhaave was deluded by mechanical opinions; or Freind's *Emmenologia* will afford some of the most singular instances, where the powers of the animal œconomy have been erroneously explained on mechanical principles; and where even the *modus operandi* of certain medicines was supposed to have been demonstrated by chemical experiments.

S E C T.

S E C T. III.

Of the Form of the Arteries, and the Nature of their Diastole.

THE principal improvement that modern anatomists have made in the doctrine of Arteriology, consists in a clear investigation of the true form of the arteries, which is an object of the first importance towards ascertaining the comparative velocity of the blood through the different branches of the arterial system; that is, the proportion that the motion of the blood in one part bears to the motion of the blood in other parts of the *arterial system*: for the comparative velocity of the blood will, *cæteris paribus*, depend on the form of the vessels, the number of ramifications, and the proportion which the sum of the areas of all the ramifications, at any given distance from the heart, bears to the area of the original trunk. But to form a tolerable idea of the motion of the blood, it is necessary first to be well acquainted with the construction of the arteries, not only *sepa-*

rately, as distinct vessels, but collectively, and to know how all the arteries united compose a perfect system of vessels, whose dimensions, form, resistance, and distance from the heart, bear such an equal proportion to each other, that in a state of health, the blood is thereby equally distributed to all the different parts of the body; for though the heart supplies the arteries with blood, and impels it through their most minute ramifications, the proportionate distribution depends alone on the action of the arteries, and not on the power of the heart. The general opinion of all anatomical writers relating to the form of the arteries was, that these vessels were parts of *long* extended cones, whose diameters decrease as they divide into more numerous branches; and even Haller† expressly mentions the conical form of the arteries, and only points out a few instances

† Haller. speaking of the pulsation of the arteries, says,
 “The *conical form* of the arteries much contributes to the
 “producing this phenomenon; for it is for this reason,
 “that the impulse of the blood against the parieties of
 “the arteries, is (in proportion to the distance) so much
 “the greater, as they are the more distant from the heart.”

Translation

instances † where the arteries are cylindrical. But the irregularity with which the blood would move through a system of vessels thus constructed, is so inconsistent with that constant simplicity that appears in every part of the animal œconomy, that this consequence is alone sufficient to prove the fallacy of this opinion.—For instance, the velocity of a column of blood propelled through a conical vessel, would, as it proceeds, increase in proportion to the diminution of the area of the vessel, so that § the velocity of the blood would vary in every part of the same vessel; and at every ramification, as the areas of the original vessel, and the additional branch, taken together, considerably exceed the dimensions of the original trunk (which may be considered as a well established and generally received opinion);

Translation of Haller's Dissertation on the Motion of the Blood, &c. p. 29.

And the Translator mentions, "That the learned author presented it to the Royal Society at Gottingen, Oct. 8, 1754, and it is published in the fourth volume of the Transactions of that learned assembly."

† *Elementa Physiologiæ*, Tom. I. p. 157.

§ *Enfield's Institutes of Natural Philosophy*, p. 85.

opinion); the velocity of the blood, which was before increasing, would at the ramification be considerably diminished, and would continue to be diminished through the succeeding parts both of the original vessel and the ramification; and these vessels being also supposed to be conical, the blood would proceed through their cavities in like manner with increasing velocity, until it arrived at those parts where these vessels gave out additional branches. Hence appears the necessity of what is now well known, that the arterial tubes are perfectly cylindrical, from the origin of the aorta to the smallest branches; and this being the true form and construction of the arteries, all the irregularities above described will be avoided, and the blood will move through every vessel with a perfectly regular velocity, which will only diminish at and in proportion to the size of the ramification; for as the sum of the areas of the branches taken together exceeds that of the artery from which they originate, the velocity of the blood will consequently be less in the small than in the large arteries: and though the motion of the blood will be equal in all parts of the same vessel, yet the

the degree of velocity with which the blood moves through the capillary arteries, compared with the motion of the blood in the aorta, will be in proportion as the sum of the areas of the capillaries exceeds the area of the aorta at its origination. As for any intermediate estimation, that could not be ascertained with any tolerable accuracy, unless we could clearly understand what was meant by the different orders of vessels, which are so expressly mentioned by some authors; as it would be impossible to trace a regular gradation from the large to the small vessels.

THEN the dimensions and strength of the different branches throughout the whole arterial system are so justly proportioned to each other, that the resistance to the pressure of the blood is in every part equal. And the quantity of blood that passes through any ramification is in proportion to the diameter of the vessel; and the resistance to the progressive motion of the blood is also equal in all parts, otherwise the distribution of the blood would not be equal in proportion to the size of the different vessels; but a
greater

greater quantity would pass through that vessel where the blood met with least resistance to its motion. This is clearly exemplified in a description that Dr. Hunter has given of a particular species of aneurysm, formed by an anastomosis* between the artery and vein, in consequence

* London Medical Observations and Inquiries, Vol. II. p. 390. "There is an anastomosis, or immediate communication between the artery and vein, at the part where the patient had been let blood, in consequence of the artery being wounded through the vein; so that blood passes immediately from the trunk of the artery into the trunk of the vein, and so back to the heart."

P. 401. "Notwithstanding the size and the force of the pulsation of the brachial artery be much more considerable than in the other arm, the artery at the wrist is much smaller, and the pulsation much weaker."

P. 407. "Why is the pulse at the wrist so much weaker in the diseased arm than in the other? Surely, the reason is obvious and clear. If the blood can easily escape from the trunk of the artery directly into the trunk of the vein, it is natural to think that it will be driven along the extreme branches with less force, and in less quantity."

P. 408. "Whence is it that the artery is enlarged all the way down the arm?"

P. 409;

quence of passing the lancet through the vein into the artery, in the operation of letting blood. The account is too long to be inserted at full length: I shall therefore only abstract such observations as are more immediately applicable to this subject. This is a very curious phænomenon, and deserves particular attention, as it affords a striking instance of the effects of diminished resistance in a part of the vascular system, independent of the influence of disease; for in cases of active hæmorrhagy, though there is a greater derivation of blood to the vessels of the part affected, yet this does not alone depend on diminished resistance, but in some degree on the increased action of the ruptured arteries.

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P. 409. "I presume that the derivation of blood to the arm by the wound of the artery, has been the cause of the dilatation of that vessel; and that, in the living body, an artery will as certainly become larger, when the resistance to the blood is taken off; as it will become smaller when it is compressed, or as it will shrink and become a solid cord, when the blood is not allowed to pass through it at all."

THE proper action and only power of the arteries is a power of contraction, which is counteracted by the systole of the left ventricle of the heart, the blood serving as a resisting medium, by which means these two powers are made to counteract each other; so that when a quantity of blood is impelled into the origin of the aorta by the systole of the left ventricle of the heart, as the resistance of the origin of the aorta is inferior to the power that would be necessary to move the whole contents of the arterial system with the same velocity that the blood is sent from the heart, consequently the origin of the aorta will give way to the lateral pressure of the blood, and will be first dilated, and this dilatation will proceed with rapidity to the extremity of all the arterial branches, and, by one progressive impulse, distend the cavities not only of the larger arteries, but of every minute ramification: for as the re-action of the origin of the aorta is greater than the resistance of the inferior branches; the anterior column of blood, which is propelled with equal power to that with which the aorta is distended, will dilate the whole arterial system until a perfect equilibrium is

is restored; and when the systole of the left ventricle of the heart is compleated, the origin of the aorta, which was first dilated, will first begin to contract; which contraction, by means of the successive action of the circular muscular fibres, proceeds to the extremities of the arteries before the returning systole of the heart.—So that the diastole of the arteries, and the systole of the left ventricle are compleated in the first instance, and the systole of the arteries, and the diastole of the left ventricle of the heart begin and end with each other.

It is this progressive dilatation and contraction that occasions what is called the pulsation* in arteries; and though both the dilatation and contraction begin at the origin of the aorta, and
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* Haller's Dissertation, p. 32. "Modern physicians say, that the pulse is produced by a wave of blood going out of the heart with more swiftness than that which preceded, and had lost its force by the resistance of the small vessels; and that the resistance which this wave makes against that which it succeeds, is the cause that its direct course is impeded, and that a part of its force is exerted laterally against the parieties of the vessels, and elevates them."

end at the extremity of the branches, yet as fluids press equally in all directions, the contents of the whole arterial system will consequently be propelled with a degree of power equal to that with which the origin of the aorta is distended, and the momentum of the blood in the extreme ramifications will be immediately affected by the impulse of the blood entering the aorta from the heart. So that although both the dilatation and contraction of the arteries is progressive, the impulse of the heart will be immediately perceptible in the distant parts, or near the circumference of the arterial system; that is, in every part where the pulsation of the arteries is evident to the senses.

I MIGHT next endeavour to estimate the power of the heart, and the degree of velocity with which the blood moves forward: and if such a discovery would considerably improve our knowledge of the animal œconomy, I should suppose that the solution of this question would not be attended with the difficulty that some have imagined; for though Borelli supposed that the power of the heart was equal to 180,000 pounds weight,

weight, and Dr. Keill's calculation reduced the force of the left ventricle to eight ounces, still these extravagant calculations will not render the task more difficult, as they both founded their arguments on equally false and erroneous principles. The experiments of Dr. Hales are very ingenious, perfectly simple, and well calculated for the intention; and, if repeated with accuracy, would nearly prove what was the power of the heart and arteries in such animals as were the subjects of the experiments. But I do not suppose that this single fact would much improve our knowledge of this subject; for though we could estimate the power of the heart by numbers or weight, it does not follow that we should have a more complete idea of the effects and extent of that power, unless we could ascertain with equal accuracy the power and resistance of every part whose motion depends on the power of the heart: for though by the power of the heart the blood is not only propelled through the arteries, but is transmitted into the veins, and its motion continued through the whole venal system to the right side of the heart, and even into the cavity of the right

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auricle,

auricle, yet it would be very difficult, if not impossible, to tell what degree of power in the heart would be necessary to produce these effects, and give motion to the blood: though it is well known, that the velocity with which the blood will flow from a punctured vein is very considerable, and that the motion of the blood first depends on the power of the left ventricle of the heart.

SECT.

SECTION IV.

Of the Systole of the Arteries, and the Motion of the Blood during the Diastole of the Heart.

PREVIOUS to describing the systole of the arteries, it will be necessary to prove that they do dilate and contract, though it is a fact so self-evident, that it appears rather singular that it should ever be doubted; for as by the systole of the heart the blood is first put in motion, if the blood continues to move through the arteries when the systole of the left ventricle ceases, that motion cannot depend on the power of the heart, but must be occasioned by some power inherent in the arteries only, by which they contract themselves, and, by a constant action, press forward the blood through their cavities. For if the arteries had no power of diminishing their cavities, it would be impossible that the blood should be discharged from a wounded artery during the diastole of

the left ventricle of the heart.—Then the manner in which the blood is discharged from a wounded artery will not only prove that the arteries do dilate and contract, but will with equal certainty explain the manner of their action: for instance, when an artery is wounded, the stream of blood does not stop when the systole of the left ventricle ceases, but continues with diminishing velocity, until the artery is again distended by a fresh supply of blood from the heart; for the velocity of the blood from the orifice of a wounded artery is greatest at that instant when the whole arterial system is completely distended, and that is, when the action of the heart is exerted with sufficient power to discharge the whole contents of the left ventricle into the aorta. From which it is evident, that the re-action of the arteries is in proportion to the degree of distention; and when the whole arterial system is in the full diastole, the re-action of the arteries, and the power of the heart which dilated them, are perfectly equal to each other. And for these reasons, the velocity of the current of blood from a wounded artery will always be equal to the

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the action of the artery: and, as was before observed, the action will be in proportion to the degree of distention; but as the contraction of the artery continues, but does not complete the vacuity of the vessel before the returning systole of the heart, the stream of blood from a wounded artery never ceases. But if the arteries were perfectly void of muscular power, and at the same time not possessed of the least degree of elasticity, and consequently absolutely incapable of either being distended or contracted, the whole contents of the arterial system would necessarily remain in a quiescent state during the diastole of the left ventricle of the heart, and the blood would cease to move in a sound artery, or flow from one that was divided: therefore, as this simple fact is uniformly the same in every instance, that the stream of blood from a wounded artery continues whilst the left ventricle of the heart is in its diastole, it not only proves that the arteries do contract, but the power of their contraction is thereby demonstrated.

To ascertain the different degrees of the power of the arteries, Dr. Hales* made an experiment, by fixing a perpendicular glass tube into one of the carotid arteries of a horse, in which the blood ascended the highest when the heart contracted, and descended during the systole of the artery; so that the weight of the column of blood in the tube was in every instance equal to the contractile power of the arteries,

ALTHOUGH Haller† has, contrary to the opinion of Boerhaave‡, positively asserted that the coronary arteries are never so situated as to admit of the possibility of being shut up by the semilunar valves, yet I suppose few modern anatomists who have attentively examined the construction of the parts in a variety of instances, will deny that such instances do sometimes exist
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* See Statical Essays, by Dr. Hales.

† Haller's Dissertation, p. 29.

‡ Boerhaave's Lectures, Vol. II. p. 153.

in nature; and where the apertures of the coronary arteries are so situated, that when the semilunar valves recede to admit the blood from the left ventricle, they fall back against the sides of the aorta, and by covering the entrance into the coronary arteries, prevent all communication between these vessels during the systole of the ventricle. But when the diastole of the ventricle takes place, and the semilunar valves approach each other, to prevent the return of the blood from the aorta; then the blood being pressed by the contraction of the whole arterial system ||, will immediately pass into the open mouths of the coronary arteries.

BUT if the arteries did not contract; when the semilunar valves were thus situated, the coronary arteries could not be supplied with blood, which, under these circumstances, evidently proves the necessity of the systole of the

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arteries;

|| Whytt, p. 24.—During the diastole of the heart, all its coronary vessels, which were in a great measure emptied by the preceding systole, are filled with blood violently pushed into them by the contraction of the aorta.

arteries; and as no other difference but the situation of the apertures is observed to attend this variety, but that the form, the size, and the strength of the coronary arteries are perfectly similar in both instances, there is every reason to conclude, that whether the blood is impelled by the systole of the heart or the systole of the arteries, the circulation through the vessels of the heart is equally perfect.

THE next consideration is, by what means this contraction of the arteries is performed; whether by an inanimate, or what has generally been termed an automatic elasticity, or by muscular power: and the complete vacuity that takes place in the arteries after death, or † when the communication with the heart is intercepted, is perhaps the only evidence that nature will afford on this important question. If the muscular coat of the arteries had never been discovered or described, their systole might then have been attributed to the former of these properties; but the very existence of muscular fibres,

† Boerhaave's Lectures, Vol. II. p. 23.

fibres, when we attend to their direction, and the nature of muscular action, is a powerful argument in support of a contrary opinion: and as the muscular coat of the arteries may be exposed to view without any great degree of anatomical sagacity, I should suppose that no one will venture to deny its existence.

NOR will the arguments that Dr. Whytt || has advanced to prove what he terms the oscillatory motion of the small vessels, more satisfactorily explain the action of the arteries, which cannot be considered as oscillatory; for if words have any precise signification, this is to suppose that at least the small arteries possess in themselves not only a power of contraction, but also a power of expansion: and if this could be demonstrated, we might then conclude, that the action of the arteries depended alone on a principle of elasticity; but as the only power of the arteries is a power of contraction, their diastole must depend on the power of the heart, and not on any inherent property of expansion;

|| Whytt's Works, p. 226. sect. 2.

panfion; for if the fyftole of the arteries depended upon elasticity, as the final contraction of the whole arterial fyftem is fo complete, that all the contained blood is transmitted into the veins, when no frefh fupply of blood* can come from the heart, thefe veffels would neceffarily remain in the fame contracted ftate; becaufe when there was no power to counteract this tendency, the arteries would be contracted to whatever degree their power of contraction was capable of exerting its influence; and as nothing but a complete contraction could evacuate the arteries, as they are found perfectly empty after death†, it is certain that they have been completely contracted, otherwife their
vacuity

* See Haller's Differtation, p. 252. or Medical Mu-
feum, p. 260. a better tranflation of Haller's original
Paper.

† Haller's Differtation, p. 56.—This phenomenon, perhaps, is the caufe that deceived the ancients, who imagined that the arteries contained only air. And p. 58.—It is always the cafe after death, that the arteries empty themfelves by degrees, until at laft they become
absolutely white, without the leaft remains of blood.

vacuity would not be perfect, but some blood would remain in their cavities.

AND as the arteries are not found in a contracted state, it is evident that their power of contraction does not depend on elasticity; for when the blood is all evacuated, the action of the arteries ceases, which undoubtedly proves to demonstration that their contraction is effected by muscular power, which is excited into action by the stimulus of the blood.

I SHALL not on this occasion (agreeable to the example of Dr. Whytt*) attempt, *à priori*, to shew the aptitude of the blood to act as a stimulus, or to enquire into the nature of the animal fibre, to prove the existence of such a property as is generally understood by what is termed the irritability of the arteries; these will appear most indisputably evident by their operations and effects: for if the arteries never cease to contract so long as the blood remains in their cavities, and as soon as the blood is impelled

* See Whytt's Works, p. 228, 229.

pelled into the veins, their action ceases, and they become perfectly passive, relaxed, and flaccid; this may certainly be considered as a clear demonstration that the contents of the arteries occasion their contraction, by exciting the action of their muscular fibres, in the same manner as the blood in the ventricles occasions the contraction of the heart: and thus the systole of the heart and the systole of the arteries depend on principles perfectly analogous to each other; for the heart and arteries are both muscular, and in both instances their muscles constantly act in the direction of their fibres when the blood is present, and immediately cease to act when the blood is evacuated.—But as the arteries have not time to complete their vacuity before the returning systole of the heart, the remaining quantity of blood will continue to excite the action of their muscular fibres, which will prevent a cessation of their contraction similar to the diastole of the heart; and in this circumstance, the motion of the heart and the motion of the arteries differ from each other, for the diastole of the arteries does not, like the diastole of the heart, depend on relaxation.

tion from the want of excitement; but is occasioned by a quantity of blood impelled from the heart overcoming their resistance, and forcibly distending their cavities; and as the power by which the arteries contract themselves will be found consistent with the nature of muscular motion, when compared with the powers and properties of other muscles, it is evident that the proper action of the arteries is perfectly muscular.

THESE arguments will also receive additional evidence from the phænomena of some diseases; for if the powers of nature admit of the possibility that one part only of the arterial system, and perhaps sometimes only a single ramification, or even only a part of a vessel is so affected, that the natural action is morbidly increased, (as in cases of local inflammation, when the action of the vessels of the part affected, and consequently the momentum of the contained fluids is supernaturally increased, and when at the same time the action of the heart, and every other part of the vascular system does not exceed the healthy standard) the

the result must be, that that increased action cannot be occasioned by the power of the heart, but must depend on some power then only existing in that degree in those arteries that are in a state of inflammation, and consequently that not only the heart itself, but every part of the whole arterial system, does possess the same property that influences their action.

WHAT this property is, would probably be difficult to determine; at least, if we look back so far, and it is to be considered as an original property of animated matter. But if a certain limitation is attended to, the laws that govern the animal functions may be made sufficiently evident, although the nature of the cause still remains unintelligible. For the power is made evident by its effects; and to be certain of the existence of the fact, is sufficient for the present occasion.—The question then is, whether, in cases of inflammation, the action of the arteries exceed the healthy standard, and whether inflammation is ever limited? and both these facts are so well known, and so universally admitted, that it must appear rather superfluous to point out

out a single instance; but as the state of the arteries is particularly evident in an inflammatory state of the tunica conjunctiva, this instance is well worthy of observation, and more so, as in all probability the hypothesis that supposes that an error loci was the cause of inflammation, first originated from this phænomenon; and also as Dr. Whytt* has made use of similar arguments nearly on the same occasion: and though he has committed some very considerable errors, yet what he has written on this subject has met with very extensive, if not general approbation. When treating of the motion of the blood-vessels, he says, “The
 “ diastole † of the arteries, like the diastole of the
 “ heart, is owing to the blood being pushed into
 “ their cavities with a considerable force;” but does not explain from whence that force proceeds: and then he adds, “That besides the
 “ alternate diastole and systole of the larger
 “ arteries, which, in a great measure, depend
 “ upon the projectile force of the heart, and the
 “ elasticity of their coats, there is a vibrating or
 “ oscillatory

* Whytt's Works, p. 53.

† Ibid. p. 213—226.

“oscillatory motion in the inferior orders of
 “vessels, to which the direct force of the heart
 “does scarcely reach, and where elasticity is not
 “concerned.” And afterwards we find a whole
 section † employed in attempting to prove by
 mathematical demonstrations, that the power
 of the heart is not sufficient to continue
 the motion of the blood through the small
 vessels.

Nothing can be more evident, than that the
 diastole of the heart and the diastole of the ar-
 teries are both occasioned by the influx of
 blood into their cavities; but, as has been be-
 fore observed, they are very different from each
 other: for as the arteries are never empty, and
 as their contraction depends on the presence of
 the blood, they are constantly in a contract-
 ing state, and require a power superior to that
 by which they do contract, to overcome their
 resistance; but as the cavities of the heart are
 nearly, if not completely emptied at every systole,
 the cause of action being removed, the heart
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† Whytt's Works, p. 230.

after every systole becomes *inactive, relaxed, and flaccid*, and consequently gives *very little* resistance to the influx of the blood, which is also much facilitated by the mechanism of the heart itself. The business of the auricles is first to receive the venal blood, the right from the two cavas, the left from the pulmonary vein; and as much less power is necessary in the right auricle to fill the right ventricle, than for the right ventricle to force it through the lungs—and in the left auricle to fill the left ventricle, than for the left ventricle to force the blood through the whole body, it is reasonable to suppose (what is evident in the construction) that the muscular power of the auricles is much inferior to the muscular power of the ventricles; and consequently that the auricles will give much less resistance to the influx of the blood, than if it was first received into the ventricles. And though it would be difficult to ascertain what degree of power would be necessary to overcome this resistance, it cannot be supposed to amount to what may with propriety be called considerable force, when compared to the force with which the blood enters the aorta; for if

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the motion of the blood alone depends on the power of the heart, the momentum must undoubtedly be diminished by friction and other causes, before it arrives at the right side of the heart. But if the inferior order of vessels (to which we are told the direct force of the heart does scarcely reach) possess an additional power of propelling the blood, it may then be possible that the momentum of the blood in the vena cava may exceed the momentum of the blood in the aorta.

BUT if this oscillatory motion is the effect of muscular motion, and the muscular fibres of these vessels are excited into action by the stimulus of the circulating fluids, they must either be in a state of constant contraction, or must empty themselves at intervals before they can become distended; and being once evacuated, the fresh supply of blood, which can only come from the larger arteries, must necessarily be forced forward by the power of the heart and larger arteries: and as Dr. Whytt has not attempted even to suppose by what means the dilatation of the small vessels is performed,

we may safely conclude, that the small vessels do not possess any inherent power of dilating themselves, more than the larger arteries; and that, agreeable to the mechanism of the vascular system, there is but one method by which both the large and small arteries can properly be dilated, and that is, the vis a tergo that originates in the power of the left ventricle of the heart.

AND as this inferior order of sanguiferous vessels to which the direct force of the heart does scarcely reach, have never yet been either discovered or described; this doctrine of oscillatory motion (where it is said that even elasticity is not concerned) is not only contrary to every known law of the animal œconomy, but there is no part of the whole vascular system where the cause of its motion is not demonstratively evident, without the necessity of any such unintelligible hypothesis.

S E C T. V.

Of the Effects of Bleeding.

FROM what has been said in the preceding Sections, it appears that the whole arterial system is in an active and contracting state, so long as the blood remains therein, and consequently the capacity of the arteries must always be in proportion to the quantity of blood which they contain; and though they will admit of different degrees of distention, without doubt there is a certain degree, beyond which if they are dilated, they lose their power of action, of which we have frequent instances in cases of aneurysm.

IN order therefore to preserve health, or to cure disease, it is necessary that an exact equilibrium should be preserved or restored between the different acting powers of the animal machine; and with this intention, when the vascular system is too much distended, either by too
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great a quantity of blood, or the action of the arteries is increased by inflammation, it is then directed to diminish the quantity of blood by phlebotomy, and there is no doubt but the whole quantity of blood will be diminished in proportion to the quantity that is taken away; and as the quantity of blood may be reduced to any degree by bleeding, this will consequently prove the most expeditious method of correcting plethora; but as frequent bleeding has a powerful tendency to promote a disposition to plethora, this * state of the constitution will be more effectually corrected by a proper management of diet, exercise, and sleep; and the lancet should never be used except there is reason to apprehend that some immediate danger will occur in consequence of the fulness of the vessels, or that the plethora is connected with an inflammatory tendency; and it is the concurrence of these two circumstances that establishes the necessity of phlebotomy—for † inflammation

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* Cullen's Practice of Physic, Vol. II. p. 167—170.

† Dr. Smith says, "It may happen, that even in inflammatory diseases, especially when they have been of
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alone, when not attended with a tension of the arteries, no more authorizes the use of the lancet than plethora without inflammation, as the inflammation may be corrected by internal medicines with less disadvantage to the patient's constitution. But here it will be necessary to observe, that there are frequent instances of local inflammation connected with local plethora, where the system is not generally affected, and which equally require the use of the lancet; and as inflammation attended with plethora is not only sometimes perfectly local, but in most instances there is one distinct part that is more immediately affected, and where the disease first originated, it has been thought more efficacious to make the evacuation from those vessels that were most contiguous to, and were supposed to be more intimately connected with that part which was the seat of the disease, with an intention

some days continuance, blood-letting may prove injurious; for if the pulse, instead of being full, high, and tense, should be low, weak, and soft, it will be expedient to excite rather than lower the *vis vitæ*; and cordials in this case will be the best remedies to resolve the inflammation."—See *Physiological Essays*, p. 126.

tion of inviting the blood to or from different parts of the body, as the circumstances of particular cases might require.

BUT as our knowledge of anatomy has improved, these opinions have been less attended to; and the different methods that are now retained in practice are bleeding in the arm, opening the temporal artery, cupping, leeches, and sometimes bleeding in the foot, in cases of suppression of the menses.

BLEEDING in the arm is most in use; and I am of opinion, that it will not be difficult to prove that this method will answer every intention, and prove preferable on every occasion where an evacuation of blood is necessary; and though in some cases, taking away a sufficient quantity of blood by any one of the above methods may be productive of evident good effects, yet as the object of bleeding is to diminish the action of the vascular system, and the momentum of the blood—and as this does not alone depend upon the quantity that is evacuated, but also in a considerable degree upon

the expedition with which the evacuation is made, and on the part from which the blood is taken, that method will without doubt be thought preferable by which the power of the vascular system is most diminished, with the least loss of blood. Dr. Cullen * observes, "That when blood-letting is necessary, it is more effectual, as the blood is more suddenly drawn off:" and Huxham † not only mentions the advantage of making a large orifice, but says, that in some instances he has seen surprising good effects from bleeding in both arms at once. But to make the truth of these observations appear more evident, it will be necessary to examine how the motion of the blood is immediately affected by the discharge from a punctured vessel.

If then, as has been shewn by Haller, a ligature was made on the superior and inferior cava ‡, the motion of the heart would immediately

* Cullen's Practice of Physic, Vol. I. p. 115.

† Huxham on Fevers, p. 178—184.

‡ Haller's Dissertation, p. 153.

diately cease, and the arteries would be no longer supplied with blood; and as the arteries would continue to contract so long as the blood remained in their cavities, the arteries would immediately empty themselves, and all the blood would be accumulated in the venal system. This evidently proves, that the power with which the veins contract is inferior to the power of the arteries; on which account the venal system becomes a more fit reservoir to receive the blood from the arteries, and to supply the heart.

THEN as the power of the heart will, *ceteris paribus*, depend on the quantity of blood that comes from the cava, that power will be diminished in proportion to the diminution of the supply of blood to the right side of the heart: and when in cases of inflammation the action of the arteries is increased, they will consequently contain less blood, and a greater quantity will be accumulated in the veins; and therefore the most effectual method of reducing the momentum of the circulation will be to diminish the quantity of blood in the cava, and as the
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greatest part of the blood that is distributed to the arm may be prevented returning to the cava by a ligature, and evacuated by an orifice in any of the veins in the bend of the arm as fast as those veins are supplied by the arteries; this will not only be found to be the most convenient part for the operation, but as any given quantity of blood may be discharged from a vein in the arm in less time than from any other part of the body, this will also prove the most effectual method of diminishing the accumulation of blood in the cava, and the power with which the blood enters the right auricle of the heart, and consequently of diminishing the power of the heart, and the momentum of the blood, in every part of the vascular system.

By way of illustration, let us suppose that by a large orifice in the arm a pound of blood is taken away in one minute, as the blood which is evacuated would have passed forward to the heart if the vein had not been opened, the quantity of blood that is returned to the heart during the operation will be less in nearly equal proportion to the quantity discharged: then as
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it seldom happens that there is any considerable degree of general inflammation without some degree of fever, suppose the number of pulsations of the heart amounted to eighty in a minute—and let it also be supposed that two ounces of blood passed the heart at every pulsation—according to this proposition, ten pounds of blood would pass the heart in one minute, the time proposed for the expeditious completing of the operation; and thus as a pound of blood is taken away from a vein during the time that ten pounds of blood is passing the heart, either a less quantity of blood must pass the heart at every pulsation during the operation, or the pulsations be less frequently performed; and Haller † informs us, that the frequency of the pulsations is not immediately influenced by bleeding: but as this is an experiment

† Haller says, “In a continual fever, many of which, and very troublesome ones, I laboured under at Göttingen, I was bled; before the operation, my pulse had 122 pulsations in a minute; it retained the same velocity during the operation, and after it was finished.”—*Dissertation*, p. 94.

ment that may be easily repeated, those who have any doubts may satisfy themselves by their own observations. Then if the pulsations continue to be performed in the same time, a less quantity of blood will be received into the different cavities of the heart during their diastole, and consequently a less quantity will be impelled into the aorta at every systole of the left ventricle, and the arteries will be less powerfully distended. But if under the same circumstances, as before stated, the same quantity of blood was by a small orifice evacuated in four minutes, as the quantity of blood that would pass the heart in four minutes would be four times the quantity that would pass the heart in one minute, the power of the heart would without doubt be diminished in much less proportion; and although these arguments will not admit of demonstrative proof in favour of the conclusion that is drawn from them, it will be right to consider, that an expeditious evacuation of blood will more frequently produce fainting than a slow one.

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THEN if by taking away any given quantity of blood by a large orifice, the power of the heart and arteries will be as much reduced as if double the quantity was evacuated with less expedition, the first method must appear preferable to the latter, because it will not so much reduce the strength of the subject; and that reduction of strength which is occasioned by a great loss of blood is not very easily recovered, but is frequently productive of very disagreeable, if not fatal consequences. The question then is, in cases where bleeding is necessary, to ascertain with accuracy how much, and only how much, ought to be taken away—and in some cases this will be a very difficult point to determine. To take away rather too much blood will be erring on the safe side; and there are but few instances where the loss of three or four ounces of blood more than the nature and circumstances of the disease may absolutely require, will prove very prejudicial to the constitution: but if, instead of a few ounces, pounds of blood are unnecessarily taken away, this becomes an object of great importance; and so large an evacuation of the vital fluids ought not
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to be ventured upon without very attentive and serious consideration.

I HOPE it will now appear evident, that by a large orifice in one of the veins in the bend of the arm, or, according to Huxham's method, in both arms at the same time, the impetus of the circulation may be reduced to any degree, with the least disadvantage to the animal economy, and so as best to promote the intention of correcting every kind of morbid affection where bleeding is particularly indicated. It remains, that we examine the nature of topical bleeding; and I shall first consider the effects of opening the temporal artery. The diseases that are supposed to require this operation depend on affections of the brain; such as in cases of apoplexy, in concussions and compressions of the brain from external injury, &c.— And even in such instances, if the intention is to prevent or diminish the increased action of the vessels of the brain, bleeding in the arm will be more advantageous than opening the temporal artery. It has been before shewn, that bleeding in the arm will most expeditiously diminish

diminish the power of the heart; and as this is effected by diminishing the supply of blood to the heart, consequently the distribution of blood to all parts of the arterial system will be diminished in proportion, and a less quantity of blood will be sent to the brain. But in addition to these effects, (which are common to all parts of the body) the plethoric state of the sinuses of the dura mater will be most effectually corrected by diminishing the quantity of blood in the cava; for as there is a perfectly free communication between the sinuses of the dura mater and the superior cava, their degree of plenitude will be nearly equal when the body is in a horizontal position, but in an erect position the blood will press downward by the power of gravity, and consequently the pressure on the brain will be thereby diminished; and for this reason it is proper, in all plethoric affections of the brain, to keep the body in an erect position. It is well known that the sinuses of the dura mater, in a natural state, contain a considerable quantity of blood—if, then, the capacity of the cranium is a little diminished by a depression, which is so occult that it cannot be discovered with

with sufficient certainty to authorize the application of the trepan, and the brain itself is no otherways affected but by the compression, there cannot be a more speedy and effectual method of giving room to the brain, than by diminishing the quantity of blood in the sinuses of the dura mater, by an evacuation from the arm; and if the brain should also be affected by inflammation, the necessity of bleeding will be increased.

BUT to return to the effects of arteriotomy.—When the temporal artery is opened, the resistance to the progress of the blood through the external carotid artery becomes less considerable, and the velocity of the blood in the external carotid artery will be increased in proportion as the resistance is diminished; so that a larger quantity of blood will pass through this branch during the evacuation, than before the temporal artery was divided—but nearly the same quantity of blood will continue to pass through the internal branch of the carotid artery to the brain: for the quantity that passes the internal carotid artery will not be diminished in proportion

proportion to the increased quantity that passes the external branch, but in the proportion that the increased quantity bears to the distribution of blood to every part of the arterial system; for as the pressure of the blood in the carotid artery at the origination of the internal and external branch is the same in all directions, the quantity that enters each vessel will be in proportion to the area of their transverse sections, and the degree of resistance. And as the resistance to the blood in the internal branch of the carotid artery that leads to the brain is neither increased nor diminished by opening the temporal artery, the quantity of blood that is sent to the brain will not be immediately influenced by the evacuation; but as a greater quantity will pass through the external branch, where the natural resistance is diminished by the division of the temporal artery, an increased proportion of blood will enter the carotid artery; and consequently, during the time that the blood continues to flow from the temporal artery, the distribution of the blood to the carotid artery will be increased, and proportionably diminished with respect to every other part of the arterial

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system,

system, and the different vessels will adapt themselves to the different proportionate quantities; and every artery will become contracted in proportion to the diminished distribution of blood, except the carotid artery, which will at least preserve the same dimensions as before the operation, if not become more dilated, as this vessel will receive an additional quantity of blood whilst the evacuation from the temporal artery is continued: so that when the intended quantity of blood is evacuated, and a bandage is applied to stop the orifice in the vessel, the blood will not only cease to flow out at the orifice, but the temporal artery will be completely obliterated by the pressure of the compress, and consequently a greater proportion of blood will pass the internal carotid to the brain for so long a time after the operation, until the whole arterial system shall have recovered a state of equal action, with the loss of a branch of the external carotid artery.—For as the carotid artery was before the operation accustomed to transmit a proper supply of blood both for the external and internal branches, this vessel will still be in a state to receive its usual

usual quantity of blood, whilst every other artery will, during the operation, have been accustomed to receive a less quantity; and as the blood cannot pass the temporal artery after the operation, every other ramification of the carotid artery will receive an additional supply of blood: and thus the internal carotid will convey a larger quantity of blood to the brain, immediately after the temporal artery is closed, than what passed to the brain before the operation took place; and for these reasons the only good effects of opening the temporal artery in morbid affections of the brain will be to relieve the plethora, by diminishing the quantity of the whole mass of blood, but by a method the most disadvantageous to that part which is the seat of the disease. The same reasoning may be used to explain the effects of the loss of blood that is occasioned by the operation of scalping; in this instance the hæmorrhagy is principally arterial, and, during the discharge, the effect will be perfectly similar to what is occasioned by opening the temporal artery; and the obstruction that takes place when the hæmorrhagy ceases, will be productive of similar effects, and in a de-

gree equal to the extent of the operation.— Then if the operation is very extensive, and a great number of vessels are divided, the quantity of blood that will pass through the external branch of the carotid artery, after the operation is completed, and the extremities of those vessels are become obstructed, will be considerably less than what passed when the parts were in a sound state, and consequently, as has been shewn before, immediately after the operation the quantity of blood that is sent to the brain will be proportionably increased; therefore, if the power of the heart and arteries has not been sufficiently reduced by the loss of blood in consequence of the operation, the necessity of taking a proper quantity from the arm by a large orifice, must appear too evident to require any further arguments.

WHAT has been said of the effects of opening arteries, will be found in a great measure applicable to the state of the arterial system in cases of hæmorrhagy; but in addition to these circumstances in cases of hæmorrhagy, there is generally an increased action of the ruptured vessels;

vessels, depending upon a phlogistic affection. This increased action frequently precedes the rupture, and is indicated by a heat and sense of fulness in the part affected, which continue increasing until the vessels can no longer resist, and consequently give way to the pressure of the contained fluids. Then when one vessel or more, as it may happen, become ruptured, the blood will meet with less resistance in those vessels, than in the other parts of the arterial system; and an increased proportion of blood will pass the ruptured vessels, and every other artery will contract in proportion to the diminution of the quantity of blood that it receives. It will be also evident, that the longer the hæmorrhagy continues, the greater will be the degree of this contraction; and if the disease is left to nature, the discharge will continue until the pressure of the blood in the arteries becomes inferior to the resistance of the ruptured vessels. The question, as proposed by Dr. Heberden, will naturally follow*: "If it be intended by
 "this practice (*i. e.* taking away blood from

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the

* Medical Transactions, Vol. II. p. 529.

“ the arm or foot) to weaken the power of the
 “ heart, and to give the lips or ends of the
 “ broken vessel a chance of collapsing, or of
 “ being plugged up by means of a more lan-
 “ guid circulation; would not all this be as
 “ likely to happen after the patient had been
 “ equally weakened from the original rupture,
 “ and in the mean time he might stand a chance
 “ of its stopping spontaneously, before he was
 “ reduced to that degree of weakness?” It is
 a well known fact, that if fainting comes on,
 the action of the heart, and consequently the
 motion of the blood; is for a short time sus-
 pended; this is proved by every day’s expe-
 rience: and I suppose few will deny, that an
 expeditious evacuation of blood by a large ori-
 fice in the arm will be more likely to produce
 fainting, than the tedious dropping of the same
 quantity of blood from the nose. If then by
 bleeding in the arm the action of the heart and
 the motion of the blood may for a time be com-
 pletely suspended, it is reasonable to conclude,
 that though the effect may not amount to
 fainting, still (as has been before shewn) the
 momentum of the blood may be reduced to
 any

any degree by an evacuation from the arm, and with the least loss of blood in point of quantity. But the object in this instance is not only to diminish the momentum of the arterial blood, but to preserve or restore the equilibrium of the arterial system: and as the discharge of blood from the ruptured vessels will have a contrary tendency, it is evident that the plethoric state of these vessels will be more effectually corrected by a discharge of any given quantity of blood from the arm *, than by a much more considerable quantity from the ruptured vessels; and if, according to the opinion of Dr. Hunter and Mr. Hewson †, the discharge is stopped by the blood coagulating in the lacerated apertures, this coagulation will not so readily take place whilst the blood is flowing through the parts, as if the necessary evacuation was made from any other vessel.

Cupping, and bleeding with leeches, are more generally practised at this present time than any other kind of topical bleeding. But after all the arguments I have heard urged on

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* Cullen's Practice of Physic, Vol. II. p. 174.

† Hewson's Experimental Enquiry, p. 68.

this subject, and after the most attentive observation, I must acknowledge that I have never met with a single instance where the superior efficacy of either method was decisively evident. I shall therefore proceed to describe how these two different methods may be supposed to operate, in the same manner, and on similar principles, on which I have attempted to explain every other part of this subject.

THOUGH cupping is generally used with an intention of more immediately evacuating the vessels of certain parts, when we consider in what manner the arteries and veins are distributed to the different parts of the body, it will be impossible to explain how cupping on the shoulder, or on any part of the chest, should more effectually correct the plethoric state of the lungs than bleeding in the arm. Indeed Huxham * writes as if he wished to recommend
cupping

* "Drawing of blood by cupping on the shoulders, &c. may be done with safety, and frequently gives exceeding great relief in disorders of the breast, as well as of the head, though the reasons may not be very obvious and assignable."

cupping in pulmonic disorders; but his reasons for preferring this method to phlebotomy do not appear to depend on a supposition that the blood that is evacuated by cupping comes more immediately from the part affected, but from an opinion that the loss of blood by cupping will not debilitate so much as if the same quantity was taken from the arm. There is no doubt but his opinion was founded on what he had repeatedly observed in practice, and is an additional proof of what has been before observed, that the immediate effects of an evacuation of a certain quantity of blood will depend in a considerable degree on the expedition with which the evacuation is made: and for this very reason, bleeding in the arm will always prove preferable when a loss of blood is necessary. The vessels that are divided by the scarificator

assignable."—Huxham on Fevers, p. 197.—And p. 212, "When I was diffident as to bleeding, I ordered scarifications and cupping sometimes with success; though in one or two cases, the effusion from the scarification was vastly profuse, and could not be totally restrained till the patient expired."

ficator are so very small, that it would be impossible to trace them by the knife from the larger branches; but it is proved by injections, that they are ramifications of the larger arteries and veins, that convey the blood to and from the surface of the body: but then these arteries bring the blood from the heart, and the veins return it to the heart again; so that the evacuation by cupping, in whatever part it is performed, will only correct the plethoric state of the lungs or brain, in proportion to the diminution of the quantity of the whole mass of blood. In this operation the arteries and veins are both cut without distinction, but the arteries will discharge the greatest quantity, for the evacuation from the veins will chiefly depend upon the influence of the exhausted cupping-glass; and thus the course of the blood being intercepted, the quantity that is taken away is prevented returning by the veins to the heart—so that the effects of cupping at the time of the operation would be perfectly similar to the effects of bleeding in the arm, if the blood was discharged with the same expedition; but the evacuation is so slow, that the impetus of the circulation cannot be

be greatly influenced by the immediate effects of the operation, in any other degree than what may be estimated by the quantity taken away: and thus, in proportion to the quantity, cupping will as effectually diminish the plethoric state of the whole vascular system, as any other method by which the same evacuation is made in the same space of time.—But it does not appear reasonable to suppose that cupping will prove particularly efficacious as a topical application.

THE use of leeches may not improperly be considered as an inferior kind of cupping; and as in this instance the evacuation is also made from the cutaneous vessels, the effects will be perfectly similar in proportion to the quantity of blood that is taken away. But it will be equally difficult to explain how plethoric affections of the brain can be relieved by the application of leeches to the temples, as by drawing off blood by cupping on the shoulders; for the vessels of these parts have no immediate connection with the vessels of the brain, except at the origin of the external and internal branches of the carotid artery, and if this can occasion any particular

particular effect on the vessels of the brain, in all probability it will be similar to the effects of opening the temporal artery. But if the quantity that is taken away by leeches is sufficient to diminish the tension of the whole vascular system, then the manner in which this operation succeeds in correcting the plethoric state of certain parts may be easily accounted for, without having recourse to the inexplicable doctrine of topical bleeding; and if the quantity is so inconsiderable that no such effect can reasonably be expected, in such instances it is most probable that the effects which are attributed to the evacuation depend on some other cause: for when a number of remedies are used at the same time, it is difficult to ascertain the powers of any one of them separately. I have been more careful and scrupulous in forming these opinions, as I know this is a method of practice which has a great number of advocates; and that I might not be deprived of the assistance of a remedy that is so generally approved, I have not only frequently directed the use of leeches, but have repeatedly attended to the whole process with the utmost diligence and circumspection,

and

and I must acknowledge that I never met with a single circumstance that appeared decisively favourable to the general opinion. But as this operation may at least be considered as perfectly innocent, in opposition to what has been advanced it may be urged, that if it does no good, it will do no harm; and indeed this at first view may appear plausible on some trifling occasions, where the disease is cured more by the effects that are produced on the mind than on the body. But if in cases (suppose of apoplexy) where a part or the whole of the vascular system is in that state, that, without proper evacuations, the powers of the animal machine cannot be long preserved; if, in such a case, an evacuation by means of leeches is depended on, and is inadequate to the purpose, and if at the same time a certain quantity taken from the arm would prove sufficient, the possibility of which I think appears evident from the preceding arguments, then the different consequences of the different decisions of the point in question will only be life or death.

F I N I S.

E R R A T A.

P. 1. line 8, for *was a subject*, read *were subjects*.

P. 59. line 7, for *proposition*, read *supposition*.

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